DAPNIA-SPP-97-32

C.E. SACLAY
DSM

SERVICE DE PHYSIQUE DES PARTICULES

FERMILAB
MAY 19 1998
LIBRARY

Fermilab Library
0 1160 0061711 2

No. M.S.

DAPNIA/SPP 97-32

December 1997

STATUS OF THE NA48 EXPERIMENT AT CERN

RETURN TO FERMILAB LIBRARY

Stéphane Schanne

DAPNIA

Invited Talk at the «XXXIInd Rencontre de Moriond» on Electroweak Interactions and Unified Theories, Les Arcs (France), 15-22 march 1997.

C91-03-15

Couverture : Sylvie Cabrit et Marc Souvage

Le DAPNIA (**D**épartement d'**A**strophysique, de physique des **P**articules, de physique **N**ucléaire et de l'**I**nstrumentation **A**ssociée) regroupe les activités du Service d'Astrophysique (SAp), du Département de Physique des Particules Elémentaires (DPhPE) et du Département de Physique Nucléaire (DPhN).

Adresse : DAPNIA, Bâtiment 141
CEA Saclay
F - 91191 Gif-sur-Yvette Cedex

STATUS OF THE NA48 EXPERIMENT AT CERN

Stéphane Schanne
CEA/Saclay, DSM/DAPNIA, F-91191 Gif-sur-Yvette, France
e-mail: Stephane.Schanne@cern.ch

(for the NA48 Collaboration *)

May 11, 1997

Abstract

The installation of the NA48 detector has been completed in 1996 with the commissioning of the liquid krypton electromagnetic calorimeter. Preliminary results from a test run performed at nominal beam intensity indicate that the NA48 detector performs according to expectations. The data taking for the measurement of the direct CP violation parameter $Re(\epsilon'/\epsilon)$ is about to start.

Preliminary results from an analysis of 1995 data for the measurement of the branching ratio of the rare kaon decay $K_L \to \mu^+\mu^-\gamma$ are presented.

*Collaborating institutes : Cagliari, Cambridge, CERN, Dubna, Edinburgh, Ferrara, Firenze, Mainz, Orsay, Perugia, Pisa, Saclay, Siegen, Torino, Warszawa, Wien.

1 Introduction

The aim of the NA48 experiment at CERN is to measure the direct CP violation parameter $Re(\epsilon'/\epsilon)$ with a precision of 2×10^{-4} [1], by comparing the relative decay rates of long- and short-lived neutral kaons into two neutral and two charged pions :

$$Re(\epsilon'/\epsilon) = \frac{1}{6}\left(1 - \frac{\frac{\Gamma(K_L\to\pi^0\pi^0)}{\Gamma(K_S\to\pi^0\pi^0)}}{\frac{\Gamma(K_L\to\pi^+\pi^-)}{\Gamma(K_S\to\pi^+\pi^-)}}\right) \quad (1)$$

The principle of the experiment is to collect all four decay modes concurrently with the same detector, using simultaneously two almost collinear K_L and K_S beams. In this way acceptances or detector efficiencies are similar for K_L and K_S decays, and accidental activity in detector elements affect both channels in the same manner. Those effects tend to cancel in (1) and reduce the systematic error. To differentiate a K_L from a K_S decay, the protons which produce the K_S particles are tagged and correlated to the time of the decay.

To collect statistics, high intensity kaon beams are used. Good space and time-resolutions for the detectors which identify the neutral and charged pions and for the proton tagging system are necessary to provide an excellent background rejection. A fast, pipelined trigger and data-acquisition system has been designed to handle the high data-rate and volume.

2 The K_L and K_S beam-line

The K_L beam is produced by a primary 450 GeV proton beam from the CERN SPS hitting a Be target at an angle of 2.4 mrad with a flux of 1.5×10^{12} protons per pulse (ppp) during 2.4 s every 14.4 s (see *figure* 1). After the target the remaining protons are deflected by a dipole magnet towards a Si bent-crystal which channels a small fraction back towards the K_L beam. This secondary low intensity proton beam (3×10^7 ppp) passes through the tagging detector before it is transported towards a second Be target for the production of the K_S beam, positioned 7.2 cm above the K_L beam line, 120 m downstream o f the K_L target. It strikes the K_S target at an angle of 4.2 mrad, such that the momentum spectra of the decayed K_S and K_L are as similar as possible in the study range (70-170 GeV/c). The K_S beam converges with an angle of 0.6 mrad towards the K_L beam. The K_S and K_L decay region starts 6 m downstream of the K_S target, at the exit of the last K_S and K_L collimators, and is defined by anti-counters. It has a length of 18 m ($\simeq 3\tau_S$) and lies inside a 90 m long vacuum tank covered with 7 rings of scintillator-counters. It is terminated by a thin kevlar window after which the central detector begins.

3 Detector elements

The proton tagging counter

The knowledge from which K_L or K_S beam a decayed kaon came from is obtained by measuring the time difference between the passage of the proton in the tagging counter and the decay seen by the hodoscope and photon detector. Events with a time difference inside a given interval are called "K_S", the others "K_L". Due to inefficiencies in the tagging counter, K_S decays can be identified as "K_L", on the other hand accidental hits cause K_L to "K_S" transitions. Those misidentification are decay-mode independent and lead to a dilution of $Re(\epsilon'/\epsilon)$.

The tagger consists of two sets of 12 successive scintillator foils. Each foil sees only a part of the proton beam section, to reduce counting rates. An overlap of 50 μm between neighbouring foils ensures an excellent geometrical efficiency. Each foil is read out by a photomultiplier tube, digitized using two 500 MHz FADC chips running in interlaced mode.

The measured time resolution for a single counter is 180 ps and its double pulse separation is better than 5 ns.

The magnetic spectrometer

The $K_{L,S} \to \pi^+\pi^-$ decays are detected using a magnetic spectrometer formed by two drift chambers for vertex identification, an analyzing magnet with a vertical magnetic field and a set

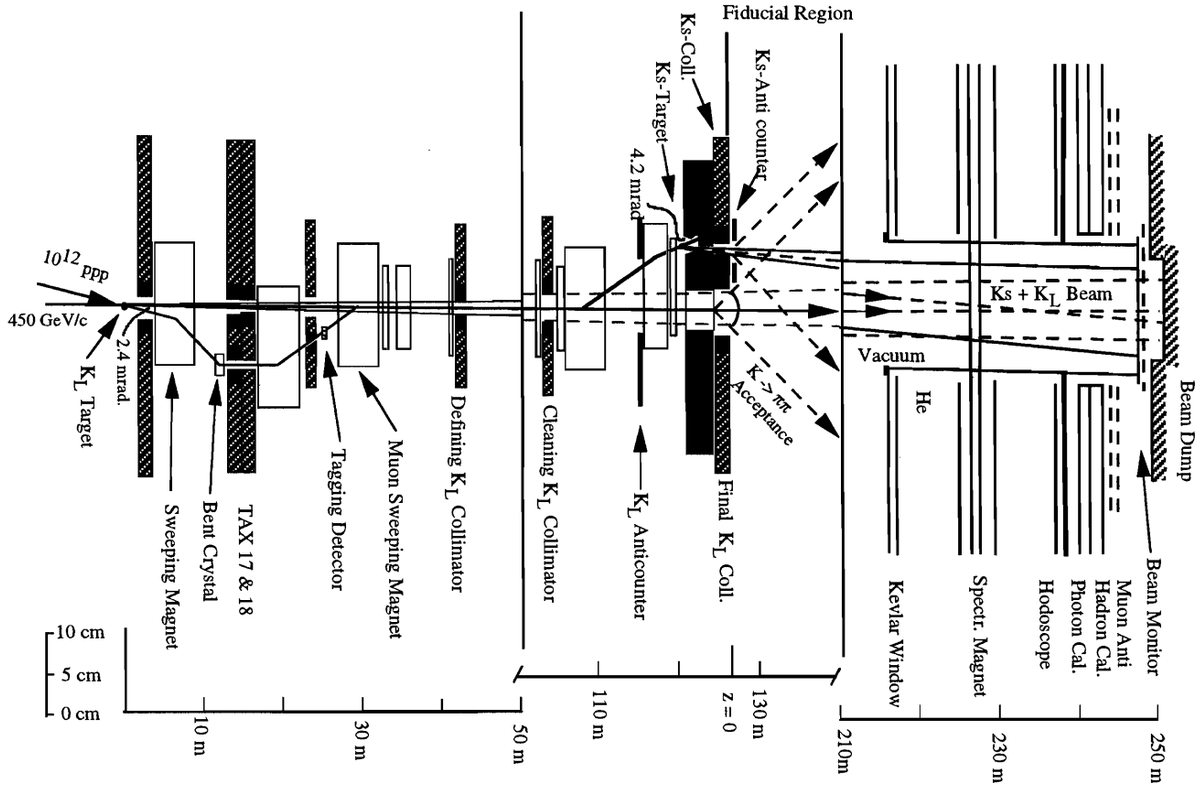

Figure 1: The NA48 kaon beam-line and detector

of two more drift chambers used for the determination of the track's bending angle. It is contained in a 22 m long tank filled with helium to reduce multiple scattering effects. It is traversed by a 1 MHz flux of charged particles.

The four 2.9 m large drift chambers have an octagonal shape. Each one contains 8 planes of 256 parallel sense wires. The planes are staggered two by two and oriented in four directions orthogonal to the beam axis to ensure an efficient and unambiguous impact point reconstruction. The electrical field in the 5 mm drift cell around a sense wire is shaped by potential wires and aluminized mylar foils operated under -2250 V and -1405 V respectively. Each sense wire is connected to ground via a preamplifier, after which signals are discriminated and digitized by a 40 MHz TDC with a 25/16 ns fine time resolution and stored into ring buffers.

During construction of the chambers, the wires were carefully positioned [3] : the 1 cm gap between two wires is known to 10 μm, the absolute transverse position of the wires to 100 μm/m. The resulting space resolution of the chambers is measured to be 120 μm in each projection and the track momentum resolution obtained is $\sigma_p/p = (0.47 \oplus 0.01\ p[GeV/c])\%$. The resolution on the reconstructed invariant mass under $\pi^+\pi^-$ hypothesis is 3 MeV/c^2 for nominal intensity K_S or K_L beams.

The charged hodoscope

The charged hodoscope consists of a horizontal and a vertical plane of 64 scintillator counters each and gives the time reference for a $K_{L,S} \to \pi^+\pi^-$ decay with a 200 ps resolution.

The electromagnetic calorimeter

The quasi-homogeneous liquid krypton (LKr) calorimeter is designed to detect the photons resulting from neutral pion decays

in $K_{L,S} \rightarrow 2\pi^0$ and to identify and reject the enormous amount of $K_L \rightarrow 3\pi^0$ background.

It consists of a 2.6 m diameter vessel with a depth of 1.25 m corresponding to 27 X_0(LKr), filled with liquid krypton mentained at a temperature of 120 K by a cryogenic system. The radiation hard krypton can stand the 1 MHz particle rate and is used both as a converter to induce showers and as the detection medium. The volume of the calorimeter is segmented into 13500 drift cells using 40 μm thick CuBe ribbon electrodes spanned through the whole depth of the calorimeter, mentained by spacer plates ensuring a local positioning precision of 50 μm by giving th e electrodes a zig-zag shape along the beam axis. A drift cell is defined by two cathode ribbons placed at 1 cm on each horizontal side of a central anode and is 1.8 cm high. A 2 mm gap separates the cells in the vertical direction.

The read out uses the initial current technique. Analogue signals from each anode are sent to preamplifiers located on the end plate, in the liquid krypton. Signals are then sent out of the cold to a shaping amplifier with an automatic 4-gain switch to cover the range of 3.5 MeV to 50 GeV with 10 bit FADCs running at 40 MHz. A zero suppression mechanism is implemented as well as a fully pipelined neutral trigger system.

The performance of a calorimeter prototype has been measured [4]. During the 1996 running period, the behaviour of the full scale detector was checked. The energy resolution achieved with a 50 GeV electron test beam is $\sigma_E/E = 0.69\%$ with a noise level of 8 MeV/cell. The space resolution in the horizontal and vertical directions have been measured to be $\sigma_x = 0.78$ mm and $\sigma_y = 0.97$ mm. It is due to the small LKr Molière radius of 4.7 cm and the 2×2 cm^2 drift cell area. The time resolution obtained after alignment of neighbouring cells and calibration was $\sigma_t = 263$ ps. Down to a 6×10^{-5} level tails in the event time distribution, mainly due to accidentals, are understood.

The hadronic calorimeter

Hadronic showers starting in the photon detector leak into a conventional Fe/scintillator sampling calorimeter with a depth of 7.2 interaction lengths and an energy resolution of $\sigma_E/E = 65\%/\sqrt{E[GeV]}$.

The muon veto system

Three layers of scintillator counters with 80 cm of iron in front of each produce signals used in the trigger logic to reject $K_{\mu3}$ decays with an efficiency better than 99% for muons above 5 GeV.

4 Trigger & data acquisition

The Neutral Trigger for the selection of $K \rightarrow \pi^0\pi^0$ decays uses the informations delivered by the LKr calorimeter in a fully pipelined mode. It computes and performs selections on the total energy in the calorimeter, the number of showers in the horizontal and vertical projections, the centre-of-gravity of the energy deposition and the position of the $K \rightarrow \pi^0\pi^0$ vertex along the beam axis. The output rate is less than 2 kHz.

A fast energy information is used together with ring anti-counter, hodoscope, muon veto and drift chamber multiplicity signals to form a fast pre-trigger to reduce the rate of $K \rightarrow \pi^+\pi^-$ candidates to less than 100 kHz.

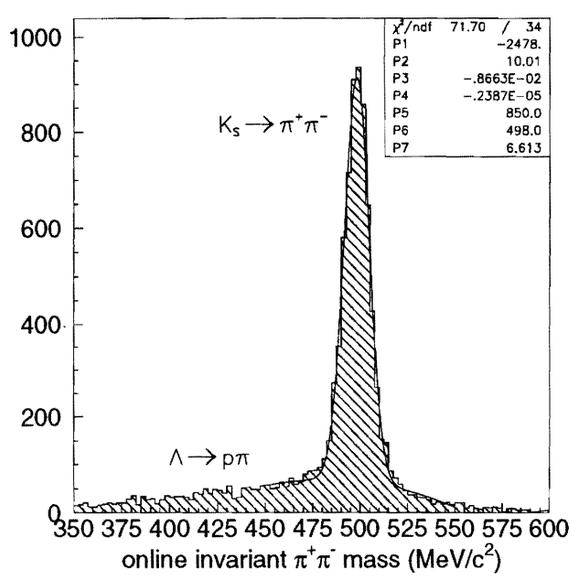

Figure 2: Charged Trigger operation (K_S beam)

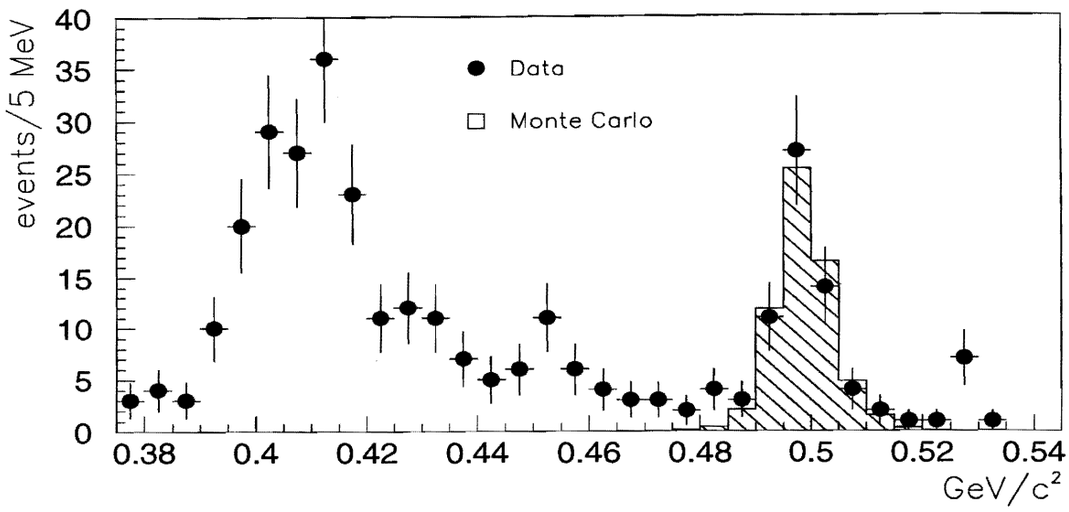

Figure 3: Invariant $\mu\mu\gamma$ mass distribution obtained with a K_L beam. The signal region is defined between 0.485 and 0.510 GeV/c^2, the background region between 0.460 and 0.535 GeV/c^2.

The Charged Trigger uses then the drift chamber information from the ring buffers to compute the vertex and invariant $\pi^+\pi^-$ mass (see *figure* 2) and cuts on those quantities reaching a reduction factor of 70. To stand the high event rate a farm of 40 digital-signal-processors reconstructs in parallel a maximum of 10 events. Due to the data persistence in the ring buffers, the maximum processing time allowed for an event is 100 μs.

During the SPS spill, accepted data (about 3 kHz) are zero suppressed, collected from all ring memories, merged together and sent at a speed of 100 MB/s into the memory of a front end workstation farm, which copies them over a 5 km optical fibre HIPPI li nk to the CERN computer centre during off-spill time, where they are stored on tape (expected volume 40 TB/yr) by an online reconstruction program.

5 Test run periods

The 1995 run

In 1995, most of the detectors were present, except the photon calorimeter. This period was devoted to commissioning of the charged part of the experiment including spectrometer and Charged Trigger. Using the hadronic calorimeter as a photon detector, it was possible to take about 100 h of data to search for the rare kaon decay $K_L \to \mu^+\mu^-\gamma$. Among the 4.2 million events selected with a trigger requiring two tracks in the hodoscope, energy in the calorimeter and two muons in the muon counters, it was possible to find 45 signal events over a background of 14, which was identified as $K_L \to \pi\mu\nu$ with an accidental γ and a subsequent $\pi \to \mu\nu$ decay. The events were selected requiring a reconstructed transverse momentum for the $\mu\mu\gamma$ combination close to zero ($p_T^2 < 0.002$ (GeV/c)^2). Furthermore the signal was enhanced by comparing the $\mu\mu\gamma$ transverse momentum (zero except for detector resolution effects) to the one of the $\mu\mu$ pair (non zero in mean) ($p_T^2/p_T^2(\mu\mu) < 0.05$), since the studied process is dominate d by $K_L \to \gamma\gamma^*$ with a subsequent $\gamma^* \to \mu\mu$ decay [5]. Photons have a shower width smaller than the granularity of the hadron calorimeter, thus the photon position was corrected by constraining $p_T^2 = 0$. The corrected $\mu\mu\gamma$ mass distribution obtained is shown in *figure* 3. To compute the branching ratio, the $K_L \to \mu\mu\gamma$ decay mode was nor-

malized to $K_{\mu 3}$ decays, selected with a looser, down-scaled trigger. Acceptances were computed by Monte Carlo simulation and relative trigger efficiencies were measured. The measured branching ratio is (in agreement with [6]):

$$Br(K_L \to \mu^+\mu^-\gamma) = (3.2 \pm 0.6 \pm 0.3) \times 10^{-7}$$

The 1996 run

The 1996 run period was devoted to the installation and commissioning of the LKr calorimeter and the implementation of the Neutral Trigger. 8% of the LKr electronics were available in 1996. The properties of the calorimeter (given above) were measured by performing a calibration of 384 individually instrumented cells with electrons at energies of 25, 50 and 100 GeV. For the study of $K \to \pi^0\pi^0$ decays and the operation of the Neutral Trigger, the rest of the acceptance was instrumented by adding 2×8 cells onto one electronics channel. $K \to \pi^0\pi^0$ decays with four showers were observed both for K_L and K_S decays and the π^0 mass resolution obtained is 2.1 MeV/c^2 (see *figure* 4). With a fully instrumented calorimeter, the resolution expected is 1 MeV/c^2. The LKr calorimeter was successfully operated at 1500 V with a temperature uniformity better than 0.2 K inside the cryostat. The electron lifetime was 45 μs during several weeks without additional purification of the krypton.

The Charged Trigger worked satisfactorily. A 6.6 MeV/c^2 resolution was obtained for the online reconstructed $\pi^+\pi^-$ mass with a K_S beam (*figure* 2) and the rejection power was studied with a K_L beam.

6 Conclusions and outlook

The results form the 1995 and 1996 test runs confirm that the charged and neutral parts of the NA48 detector work accordingly to expectations at the nominal $K_L + K_S$ beam intensity. For the 1997 run all LKr electronics will be installed and tested, permitting an operation of the calorimeter with the final granularity. Additional processors and electronics modules will [illegible] for the Charged and Neutral Trigger [illegible] higher event rates.

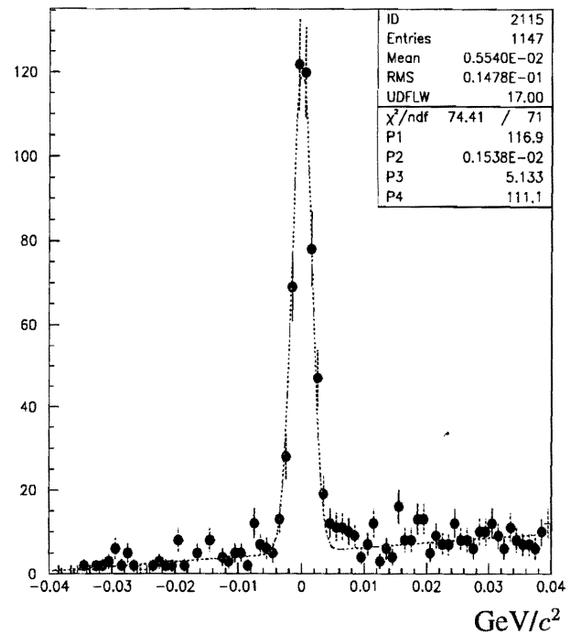

Figure 4: $(m_{\pi^0(1)}+m_{\pi^0(2)})/2-m_{\pi^0}$ distribution in $K_L \to \pi^0(1)\ \pi^0(2)$ decays detected with a 2×8 cell granularity in the LKr calorimeter.

For 1997, 120 days of beam time are scheduled from April on. With an overall 50% efficiency, 50000 $K_L \to \pi^+\pi^-$ and 20000 $K_L \to \pi^0\pi^0$ CP violating decays are expected per day, and 3 times more for the CP conserving K_S decays. The aim for the 1997 run is to supersede the statistical precision of the NA31 experiment [7] for the $Re(\epsilon'/\epsilon)$ measurement.

References

[1] Barr et al., CERN/SPSC/90-22/P253

[2] Grafström et al., NIM A344(1994) 487

[3] Béderède et al., NIM A367(1995) 88

[4] Barr et al., NIM A370 (1996) 413

[5] Bergström et al., PL B131(1983) 229

[6] Spencer et al., PRL 74(1995) 3323

[7] Barr et al., PL B317(1993) 233